GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: February 25, 1980

Project Title: GAC Analyses for BET and Pore Size Distribution

Project No: A-2584

Project Director: Dr. S. B. Smith

Sponsor: Manchester Water Works; Manchester, New Hampshire 03103

C.O.

Agreement Period: From January 31, 1980 Until Open

Type Agreement: Purchase Order No. 41248

Amount: $1,200

Reports Required: None specified

Sponsor Contact Person (s):

Technical Matters

Mr. David Faris
Plant Manager/Chemist
Manchester Water Works
281 Lincoln Street
Manchester, New Hampshire 03103
(603) 668-3830

Contractual Matters
(thru OCA)

Defense Priority Rating: None

Assigned to: CMSL/MSD (~~School~~/Laboratory)

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GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

NK

Date 10/2/81

Project Title: GAC A nalyses for BET and Pore Size Distribution

Project No: A-2584

Project Director: Dr. S. B. Smith

Sponsor: Manchester Water Works; Manchester, New Hampshire 03103

Effective Termination Date: 9/30/81

Clearance of Accounting Charges: 9/30/81

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______________________

Assigned to: EMSL (School/Laboratory)

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Other ______________

FORM OCA 10:781

EES ENGINEERING EXPERIMENT STATION Nancy McHan

A-2584

MEMO DATE Nov. 26, 1980

TO: ~~Henry~~ Gerry Henry (OCA)

FROM: S. B. Smith

SUBJECT: Manchester (N.H) Water Works, Proj. A2584-001

With the mailing of this report we can proceed with billing of the second installment on A2584 for $4000 (fixed price) against their P.O. #43344. The project should be left open as further samples are expected against another purchase order.

Billy Atcheson and Nancy McHan are being notified by copy of this memo.

Please note that since we were not aware of the "001" subnumber in time some charges were made against A2584. All charges remaining on A2584 should be transferred to A2584-001

H. O Spauschus
B. Atcheson
N. McHan

TC OK
complete pkg for files

911 (8/79)

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

November 25, 1980

Mr. David Paris, Plant Manager/Chemist
Manchester Water Works
281 Lincoln St.
Manchester, N. H. 03103

Project No.: A-2584-001

Dear Mr. Paris:

The report covering your eight carbon samples received on 9/16/80 representing two thermal regenerations is attached. There are some missing bits of information--the BET area and the nitrogen pore-size distribution on Sample No. 5 (after calcination). All the other samples were run just before a 3-week shutdown of the instrument took place. I had a choice of which sample to omit and I picked #5. So as not to hold you up any longer, we completed the report with this information omitted. Work will soon resume on the Digisorb 2500 unit and this sample will be in the first set analysed. Revised tables and graphs can be substituted when completed without additional cost to you.

There are some problems in interpreting these results but I credit this mainly to the sampling problem both on your end and here as well. The BET areas are particularly vulnerable since only a little over 1/10 gram of granular material is used. This, of course, was not riffled down to the last fraction as in case of most of the other tests.

I hope this information will be meaningful and will tie in with other observations and conditions. Perhaps you can supply answers to the problems presented by samples #1 and #2, and #7 and #8.

I hope you will be sending additional samples. We will try to complete the next set more quickly. Please let us know when to expect another set. If there are questions, I would welcome a phone call which may either confirm or refute my interpretations.

Very truly yours,

Stanton B. Smith, Ph.D.
Principal Research Scientist

xc: H.O. Spauschus
G.R. Henry (OCA)
File
Extra (1)

SBS:mla

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

REPORT TO MANCHESTER WATER WORKS
EVALUATION OF FIRST AND SECOND CYCLE CARBON, WVW 8x30
FROM MANCHESTER, N. H. WATERWORKS

Project No. 2584-001

SUMMARY AND GENERAL COMMENTS

The analytical results on eight samples received September 16, 1980 representing two successive thermal regenerations by the Westvaco fluid-bed technique indicate an efficient restoration of adsorptive characteristics with a minimum of deleterious physical changes. The analytical data are tabluated in "Certificates of Analyses" for each sample, and Summary Tables I and II. Complete sets* of "Micromeritics" Digisorb 2500 computer read-out sheets covering the nitrogen adsorption data are given for each sample. It should be noted that the "Spent" samples #1, #2, #5, and #6 were calcined one half hour at 1500°F in a stream of nitrogen to destroy volatile organic matter and to carbonize the residues before running the nitrogen adsorption data. Apparent Densities were run on these calcined samples but all other data were determined on the samples "as received" except for oven-drying at 105°C.

Figure 1 shows the data on a "specific volume" basis plotted against sample Sequence No. as to indicate trends as graphically as possible. Screen Analyses "as received" and after abrasion are shown in Figures 2-9. The Phenol Isotherms are given Figures 10 and 11. The Cumulative Pore-size Distributions calculated from the nitrogen desorption isotherms are shown in Figures 12-14. A thorough discussion follows but the overall effect of two adsorption and regeneration cycles is most easily seen in Table I, where the averages of the "Spent" and "Regenerated" pairs have been tabulated on a "specific volume" basis for the activity factors. The last column gives the corresponding values for the Virgin Carbon sample which was included in the first set of samples, but not with this set.

Over two regenerations, there has been a slight decrease in BET sur-

* With client and file copies only

face area, but this is not regarded as significant as the Iodine No. (by volume) is substantially higher than that of the virgin carbon while the Apparent Density is only slightly lower. The Modified Phenol Value has increased very slightly. Since this is a reciprocal value, 100/MPV is also shown which is proportional to phenol capacity. There is a 6% drop in this quantity indicating that perhaps some of the finest, most retentive pores have been lost. Such a small apparent change is, however, not regarded as significant. The molasses decolorizing Index (DI) which was very low in the Virgin sample has increased by 50% over two regenerations. Thus, the activity parameters look very good and in keeping with the usual trends for efficient regeneration.

There is an increase in ash content in each adsorption cycle which could be serious later if it doesn't level off after a number of cycles due to make-up additions of virgin carbon of lower ash content. All the particle size data is quite favorable. The MPD has dropped about 6.2% per cycle, some of which is probably shrinkage and does not reflect burning loss. Only slight changes are noted in the Effective Size and the Uniformity Coefficient showing a slight attrition of particles and a trend toward a narrower, rather than a wider size distribution. Make-up with coarse carbon should halt this trend without any problem.

The Apparent Density has dropped only 2.6% per cycle, showing that there is good control of "burn-off" in spite of very light loading in the adsorption, or "use," cycle. The Abrasion No. has apparently increased, indicating no tendency toward softening and, is probably the result of a reduction in softer particle surfaces or removal of easily abraded corners, etc. on the granules as transfer and backwash operations are carried out.

Overall, this regeneration shows burning control as good as can be hoped for in view of the light loading on the spent carbon.

DISCUSSION OF RESULTS

This set of eight samples represents an interesting series of events which may be interpreted on the basis of both physical (mechanical) and chemical changes that have occurred and it is tempting to interpret even the most minute observation. However, it must be remembered that the results are only as good as the sampling, which in such a system is a very diffi task. We will try to avoid this pitfall in the analysis given below.

If it weren't for the transfer operations involved we would have only four samples: 1st Spent, 1st Regenerated, 2nd Spent, and 2nd Regenerated. Perhaps the most valid comparison could be made by averaging each of these pairs, thus ignoring the transfer steps in so far as activity levels are concerned. The averaged activity data is shown in Table I. These data have been reviewed in some detail above in the summary.

With the above reservations we may, however, examine the "transfer pairs" for evidence of particle size changes. In the case of transfer to a filter the effect on the particle size depends on whether or not the charge was backwashed (with accompanying loss of fines) before the samples (#4 and #8) were taken. Table II summarizes all the data on both a weight and volume basis. These values have been plotted in Figure 1 against Sample Sequence No. to indicate trends.

At the bottom of Figure 1 one sees very little change in Mean Particle Diameter (MPD) from #1 to #6. However, on the second regeneration the MPD appeared to drop about 0.2 mm but then partially recovers (increases) when transferred to the filter (#8). The same change is reflected in the Effective Size which emphasizes the fines content. These changes are not seen between Samples 3 and 4, which makes one suspicious that the apparent loss of fines is not real.

During the "use" cycle, covering many backwashings, both the MPD and effective size increased slightly as would be expected. Both regeneration cycles; 2→3 and 6→7 show decreases in both of these parameters. Overall there appears to have been surprisingly little change in particle size indicating a well-designed transfer system and a well-controlled regeneration.

Another critical property in regeneration is the Apparent Density (AD) since this indicates whether the particles have been over-burned. A spent sample will have a higher than normal density due to pickup of adsorbed ubstances, both organic and inorganic. There is poor agreement between and #2. With #1 being high in both AD and Volatile Matter (VM) while is atypically low in VM. These discrepancies may be due to unevenly tributed adsorbate within the filter or to non-representative sampling.

Across the two regenerations there is a slight drop in AD - and in the second this happened in spite of an increase in Ash content which occurred during the on-stream use cycle. The ash increase from 3.7 to about 4.2 g/100ml is rather high but still would amount to only a .005 g/ml increase in AD, or ½ division in Figure 1. The dotted lines connect the densities of the Calcined Spent samples. These levels are remarkably close to the regenerated samples indicating that there was very little, if any, carbonized deposit remaining in the samples after calcination.

The activity levels shown in Figure 1 are plotted on a "specific volume" basis. This focuses attention on a given volume quantity of carbon which fills a filter compartment regardless of changes in density which occur across the complete cycle.

Iodine Number (IN) which is a reflection of the total available surface area shows in general the expected trends; somewhat low values for the spent samples and higher values for the regenerated ones. The drops in IN from #3 to #4 and #7 to #8 are not expected and cannot be explained. Likewise, the apparent increase in VM on these same pairs cannot be explained. A very "dirty" transfer water could possibly have this effect but this is very unlikely. The "use" cycle shows a decided drop in IN as expected. Overall, there has been a very slight drop off in IN, but this amount is not significant.

The BET N_2 Surface Areas (BET) in general parallel the IN's as expected. However, since the spent samples were calcined in nitrogen, one would expect the BET Areas to be almost as high as the regenerated samples. The regenerated samples #3, #4, and #7 appear almost identical at levels typical of fresh carbons. The drop in #8 is still unexplainable, as in the case of the IN. It may be influenced by loss of overactive fines, but we would not expect it to amount to this much.

The Decolorizing Index (DI) very closely follows the Phenol Capacity (PC) across the entire sequence. Though DI is a function of large pores, >30Å diameter, and the Phenol Capacity is a function of very small pores, DI and PC move more or less together indicating that both pore ranges are responding to regeneration. In the spent samples there is more indication of saturation in the DI than in the PC. In the case of the DI's the level is so low, even for the virgin carbon, that the large pores account for only a small part of the adsorptive action. The apparent small changes in Phenol

Capacity may be due to the volatility of the materials saturating the spent carbons. The drying of the samples at 105°C in air may have been sufficient to restore a significant part of the phenol capacity.

The Nitrogen Pore Size Distribution curves are shown in Figures 12, 13, & 14. These are plotted on a weight basis and so should <u>not</u> be compared directly with Figure 1. If one superimposes these curves, it is obvious that 5 out of 7 samples analyzed are virtually identical over the entire measured pore range of 20 to 600Å. diameter. The exceptions are sample #2C and #7. The former, having the lowest curve, being a calcined spent sample and the latter (highest curve) being a regenerated sample taken at the quench tank. The #2C sample appears to be lower in pores principally between 30 and 300 Å, and #7, the regenerated sample, shows greater pore volumes over the entire range, but principally from 20 to 200Å. This carbon also has the lowest density. The #4 and #8 regenerated samples have a cross-over in the fine pore range from 20Å down to the N_2 molecular diameter. This indicates a slight reduction in pore area for #8 in the less-than-20Å range. This could be the reason for the slightly lower phenol capacity but its significance is questionable.

Signed:

Stanton B. Smith, Ph.D.
Principal Research Scientist

TABLE I

SUMMARY OF FIRST AND SECOND CYCLE REGENERATION DATA
ON WVW 8x30 CARBON AT MANCHESTER WATERWORKS

Project No. A-2584-001

Property		1st Cycle		2nd Cycle		Virgin*
Per Unit Volume	Units	Spent	Regen'd	Spent	Regen'd	
BET Area	m^2/ml	453.2c	481.4	415.3c	467.6	484
Iodine No.	mg/ml	504	599	489	556	488
Mod. Phenol Val.	$ml/10^6 g$	37.0	34.6	47.3	37.6	35.5
Phenol Capacity	$gx10^4/ml$	2.70	2.89	2.11	2.66	2.82
Decol. Index	DIU/ml	2.49	3.23	2.21	3.00	2.0
Ash	g/100ml	3.70	3.68	4.24	4.29	3.33
Vol. Matter	g/100ml	6.49	3.31	7.69	3.05	4.13
App. Density	g/ml	.647	.593	.608	.582	.614
" " (Calc'd)	g/ml	.604c		.571c		
Weight Basis						
Mean Part. Diam	mm	1.429	1.306	1.367	1.243	1.42
Abrasion No.	% Mean PD	84.6	83.4	81.8	81.6	77.7
Eff. Size	mm	.82	.76	.82	.77	.81
Unif. Coeff.	-	1.84	1.84	1.73	1.71	1.96

* From first report, Proj. No. A-2584, April 30, 1980

c Determined on a portion of the sample calcined in N_2 ½ hr @ 1500°F

TABLE II

SUMMARY TABLE

Project No. A-2584-001

MANCHESTER WATER WORKS FIRST AND SECOND REGENERATIONS OF WVW 8x30 ACTIVATED CARBON

PROPERTY	SAMPLE NO.:	1 SPENT		2 SPENT		3 Regen #1		4 Regen #1		5 SPENT		6 SPENT		7 Regen #2		8 Regen #2	
		by wt.	(by vol)	by wt	(by vol)	by wt.	(by vol)	by wt.	(by vol)	by wt.	(by vol)	by wt.	(by vol)	by wt.	(by vol)	by wt.	(by vol)
BET Area	m^2/g	814.03*		686.79*		808.6		816.27				729.93*		854.08		754.28	
	m^2/ml		(494.9)*		(411.4)*		(476.3)		(486.5)				(415.3)*		(489.3)		(445.8)
Iodine	mg/g	780		778		1054		970		798		811		1015		896	
	mg/ml		(520)		(488)		(620.8)		(578)		(486)		(492)		(581.6)		(529.5)
Mod. Phenol	ppm	25.3		22.6		20.3		20.7		29.3		28.2		20.0		23.8	
Value (WV)	$ml/10^6g$		(37.9)		(36.0)		(34.5)		(34.7)		(48.1)		(46.5)		(34.9)		(40.3)
(AWWA)	g/l	2.88		2.58		2.31		2.36		3.34		3.21		2.28		2.71	
	mlC/l		(4.32)		(4.11)		(3.93)		(3.96)		(5.48)		(5.30)		(3.98)		(4.59)
Mol. D I	DIU/g	3.8		2.9		5.7		5.2		3.4		3.9		5.5		4.8	
	DIU/ml		(2.53)		(2.45)		(3.36)		(3.10)		(2.07)		(2.36)		(3.15)		(2.84)
Moisture, wb	%	5.70		4.58		2.25		3.32		5.24		3.98		1.40		3.19	
	g/100ml		(3.80)		(2.87)		(1.33)		(1.98)		(3.19)		(2.41)		(0.80)		(1.89)
Ash, db	%	5.42		6.03		6.29		6.13		6.99		6.95		7.54		7.21	
	g/100ml		(3.62)		(3.78)		(3.70)		(3.65)		(4.26)		(4.21)		(4.32)		(4.26)
Vol. Matter	%	14.93		4.81		3.81		7.33		13.52		11.78		4.25		6.20	
	g/100ml		(9.96)		(3.02)		(2.24)		(4.37)		(8.23)		(7.14)		(2.44)		(3.66)
App. Dens.	g/ml		(0.667)		(0.627)		(0.589)		(0.596)		(0.609)		(0.606)		(0.573)		(0.591)
(calcined)	g/ml		(0.608)*		(0.599)*						(0.573)*		(0.569)*				
Screen Analyses																	
On 10 U.S.Mesh	%	17.00		13.62		9.61		11.65		8.67		10.96		5.01		8.18	
10x12	%	12.62		12.13		8.71		10.37		11.37		12.95		7.11		12.48	
12x16	%	40.36		41.55		38.04		36.33		45.26		39.94		32.43		41.52	
16x20	%	19.38		22.77		25.43		24.48		25.12		23.41		29.03		23.25	
20x30	%	7.46		7.75		12.31		12.14		7.28		9.26		17.12		8.78	
30x40	%	1.89		1.69		4.60		3.06		1.30		2.19		7.51		2.79	
Thru 40	%	1.29		0.99		1.30		1.97		1.00		1.29		1.80		2.99	
Mean PD	mm	1.446		1.411		1.290		1.321		1.365		1.369		1.165		1.321	
Median PD	mm	1.40		1.38		1.25		1.28		1.30		1.34		1.10		1.28	
Abr. No	%mean	85.65		83.52		82.55		84.31		81.48		82.15		77.88		85.29	
	%median	87.1		84.8		80.8		83.6		84.6		82.1		76.4		89.1	
Eff. Size	mm	0.84		0.80		0.78		0.73		0.85		0.79		0.72		0.82	
Un. Coeff.		1.79		1.88		1.77		1.90		1.65		1.81		1.71		1.70	

* Based on a calcined portion of the "spent" sample.

FIGURE 1 Project No. A-2584-001

PROPERTY TRENDS OF GRANULAR ACTIVATED CARBON
WITH USE AND THERMAL REGENERATION

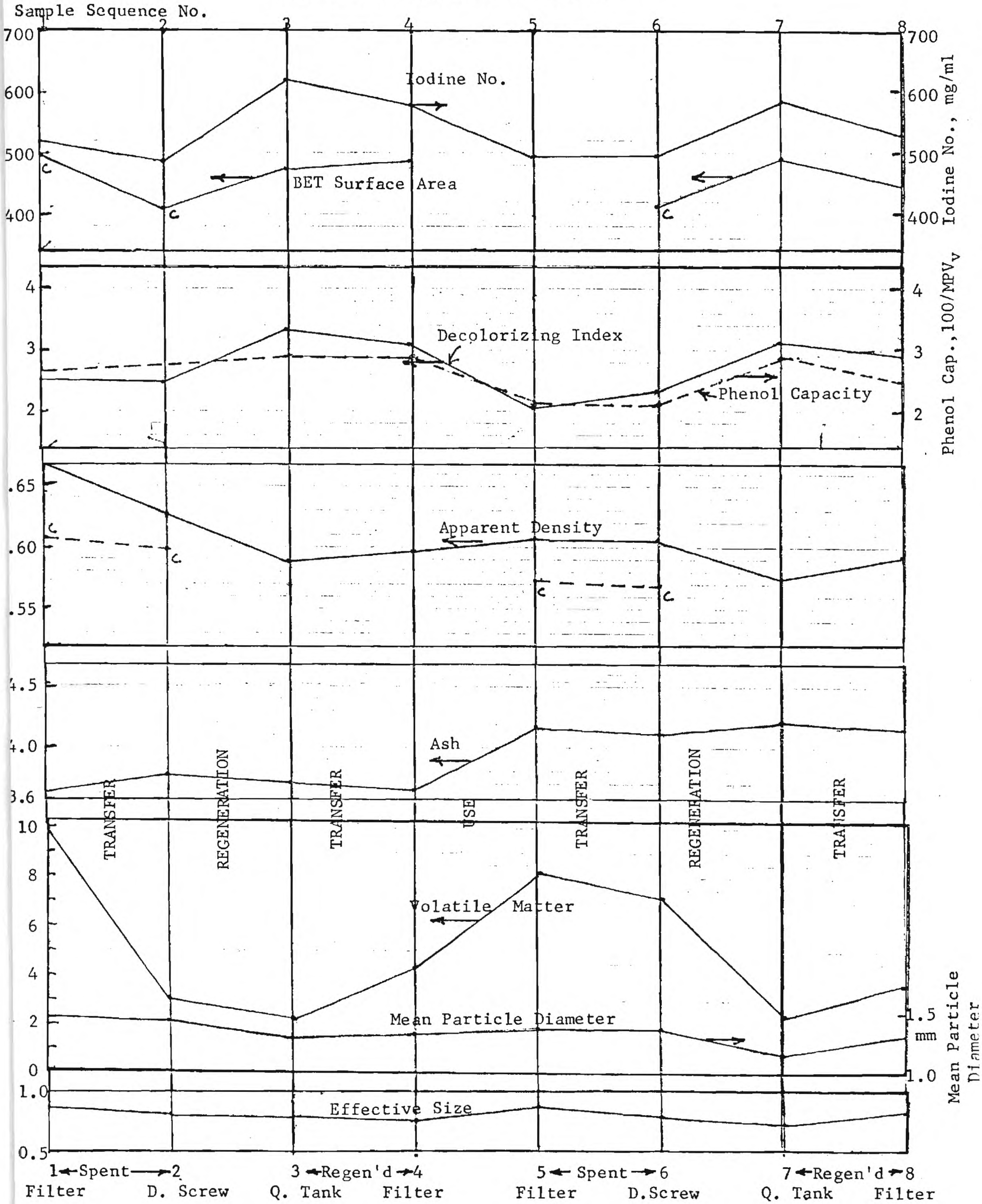
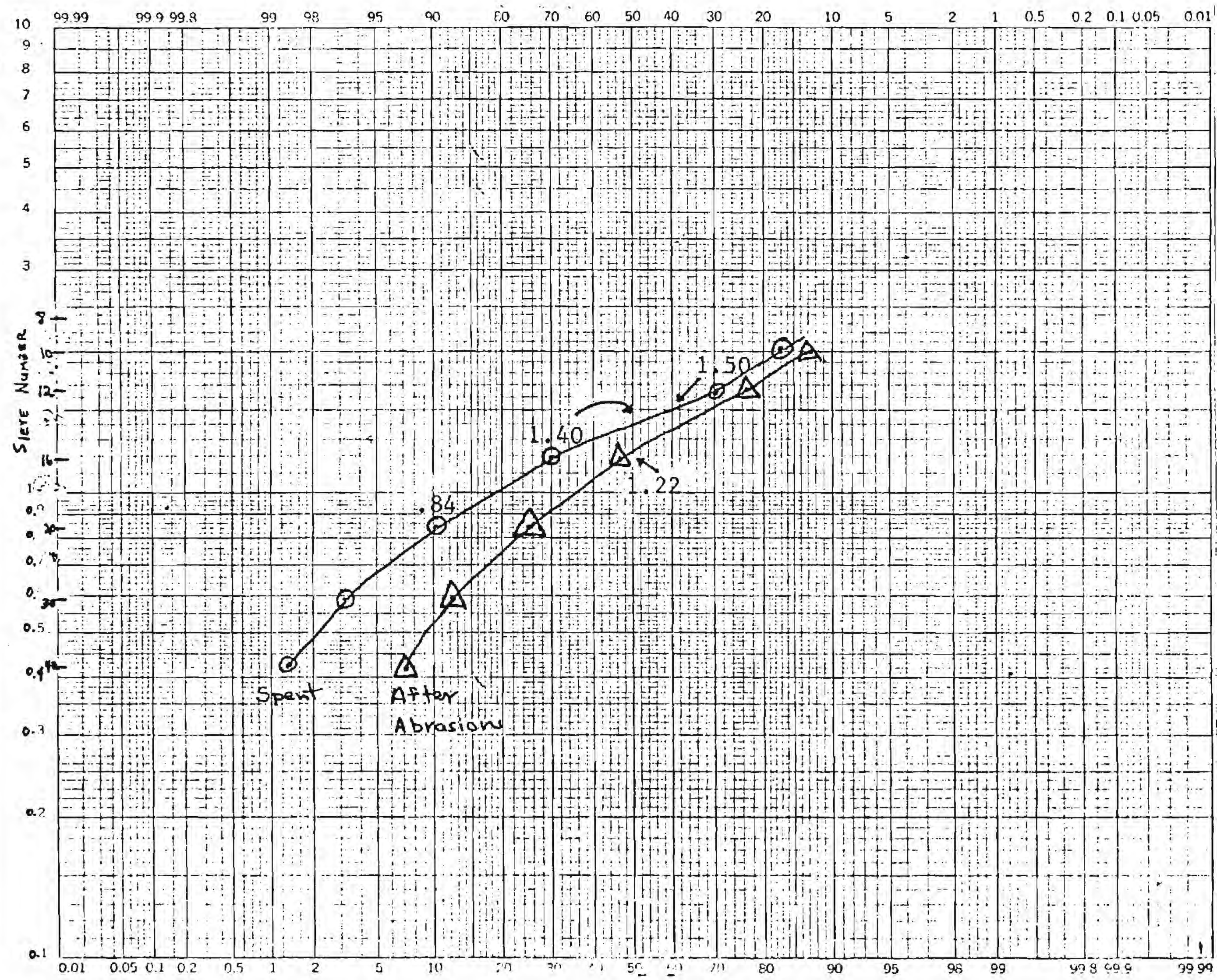


FIGURE 2

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS
No. 1 - Spent

ells 11,22,33

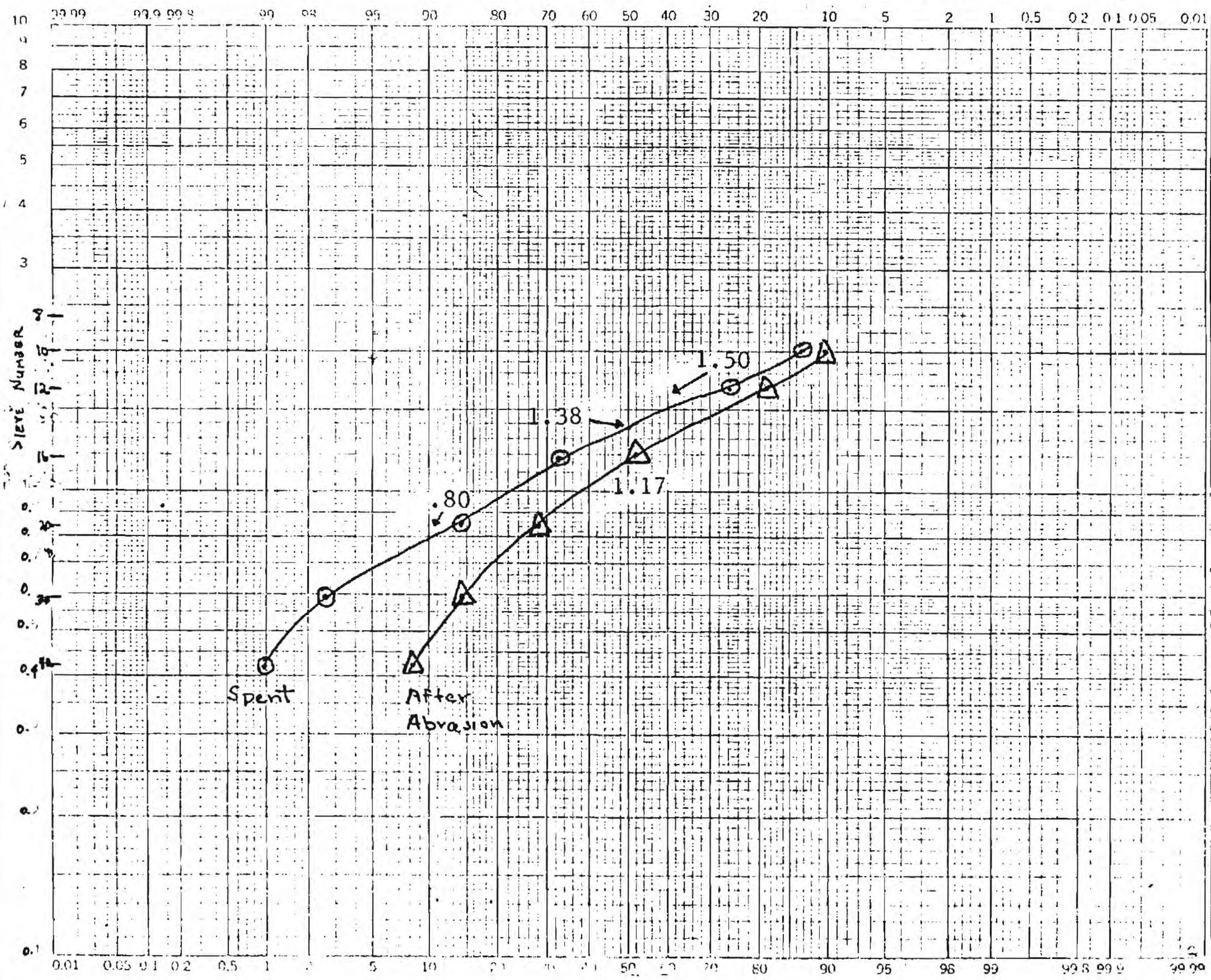


Cumulative % Passing

FIGURE 3

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS
No. 2-Spent Virgin DS-1

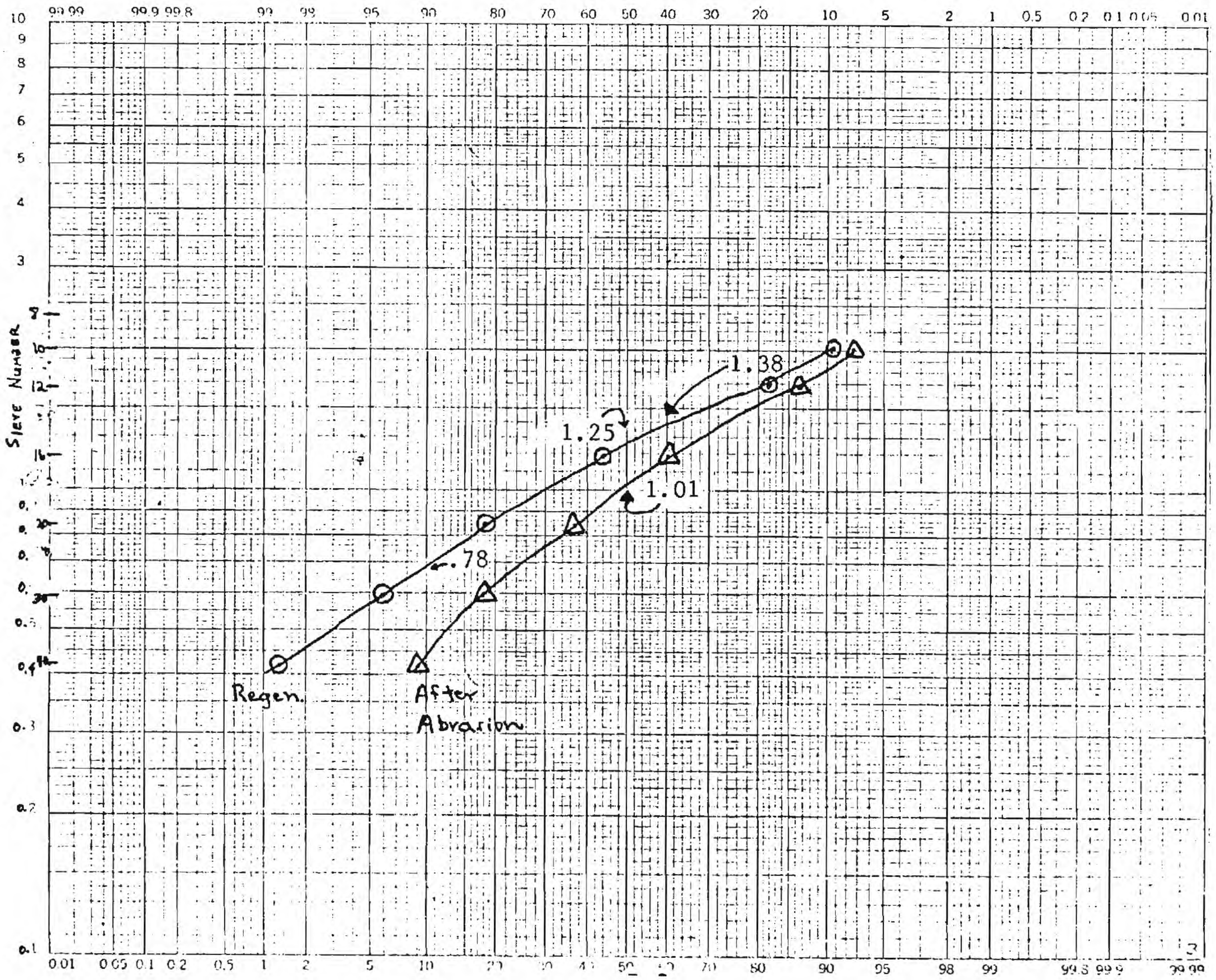


Cumulative % Passing

FIGURE 4

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS
No. 3-Regenerated Virgin-QT1



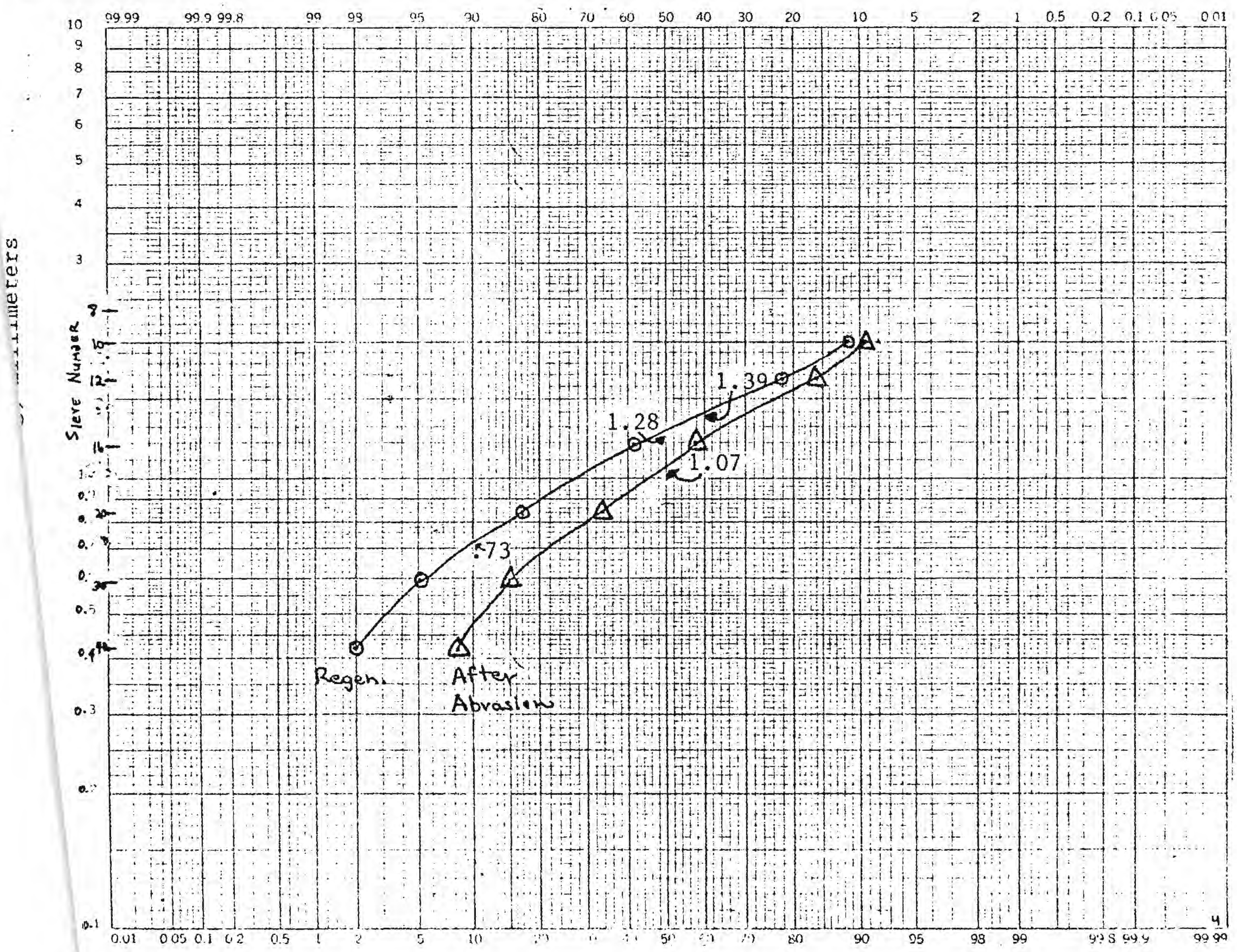
Cumulative % Passing

FIGURE 5

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS
No. 4-Regenerated

Cells 11,22,33



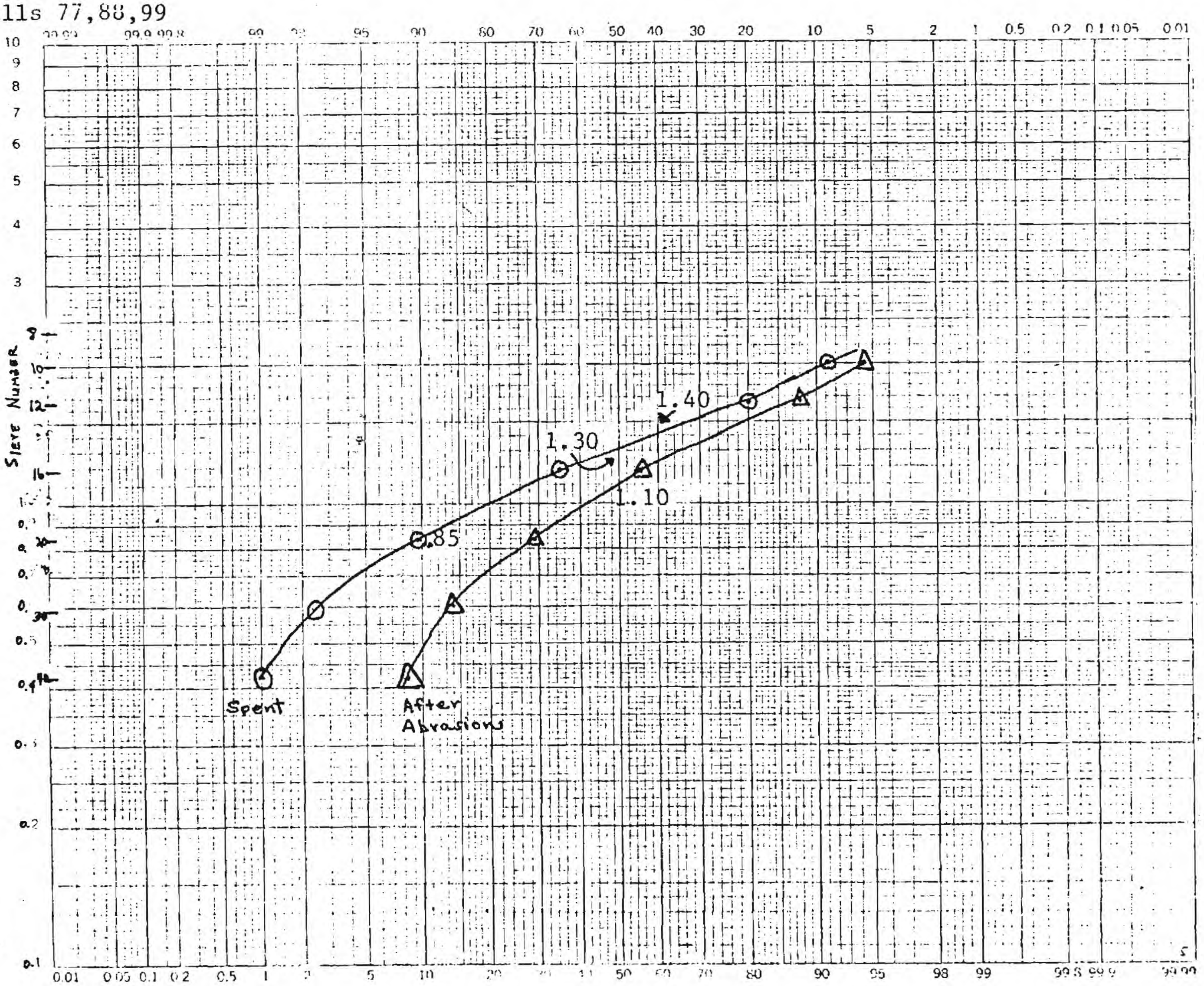
Cumulative % Passing

FIGURE 6

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS
No. 5 - Spent

Cells 77,88,99



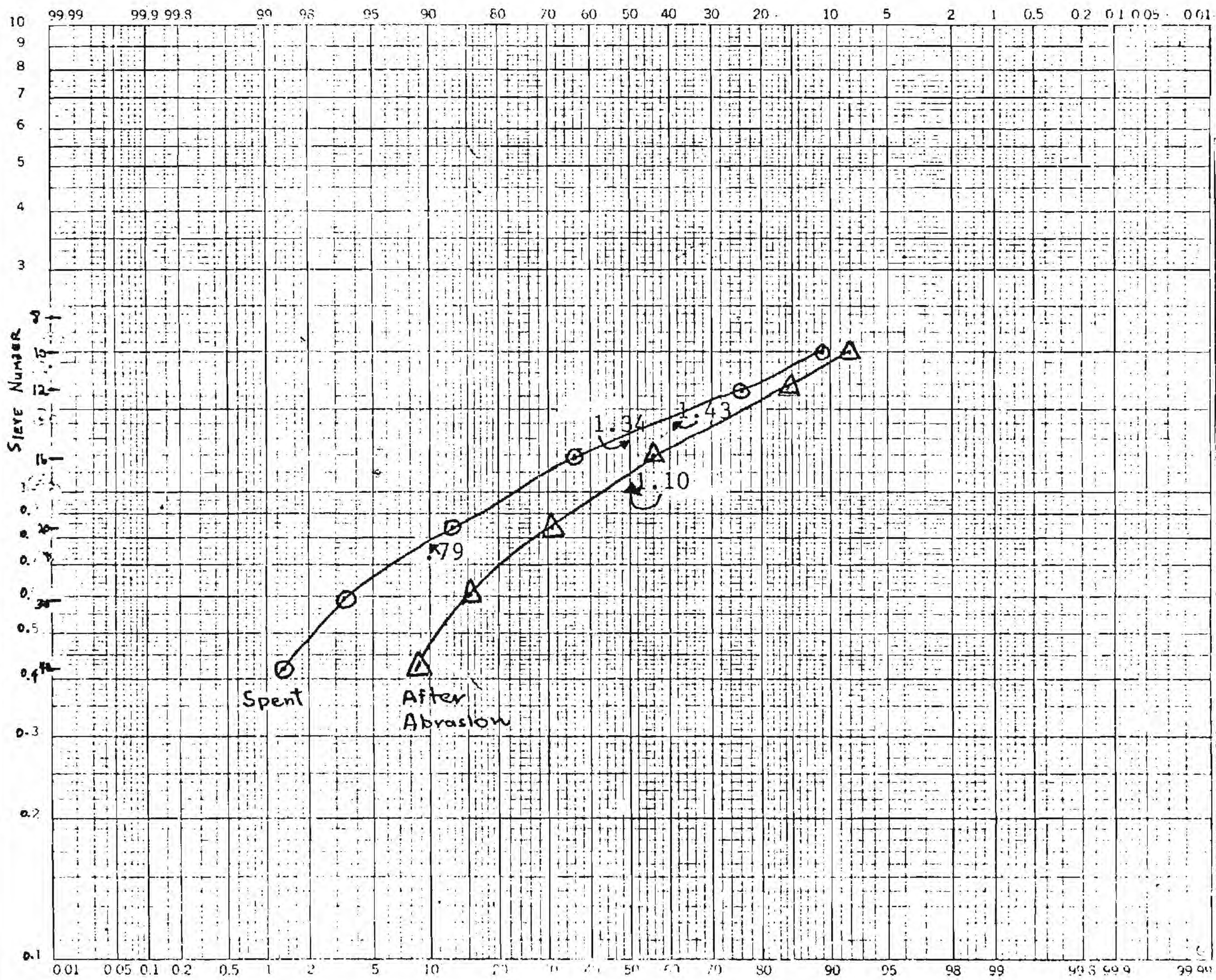
Cumulative % Passing

FIGURE 7

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS

No. 6 Spent

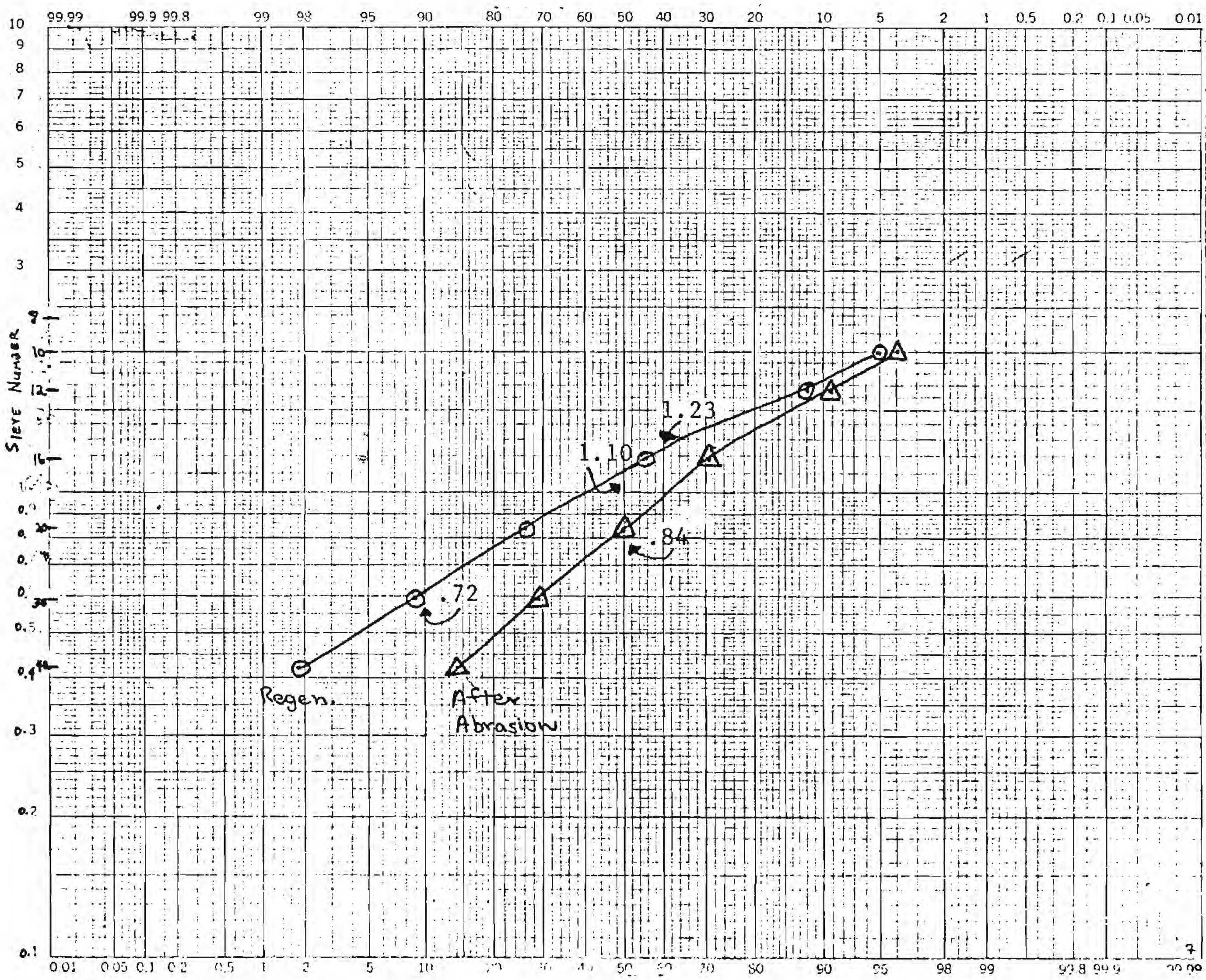


Cumulative % Passing

FIGURE 8

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS
No. 7-Regenerated



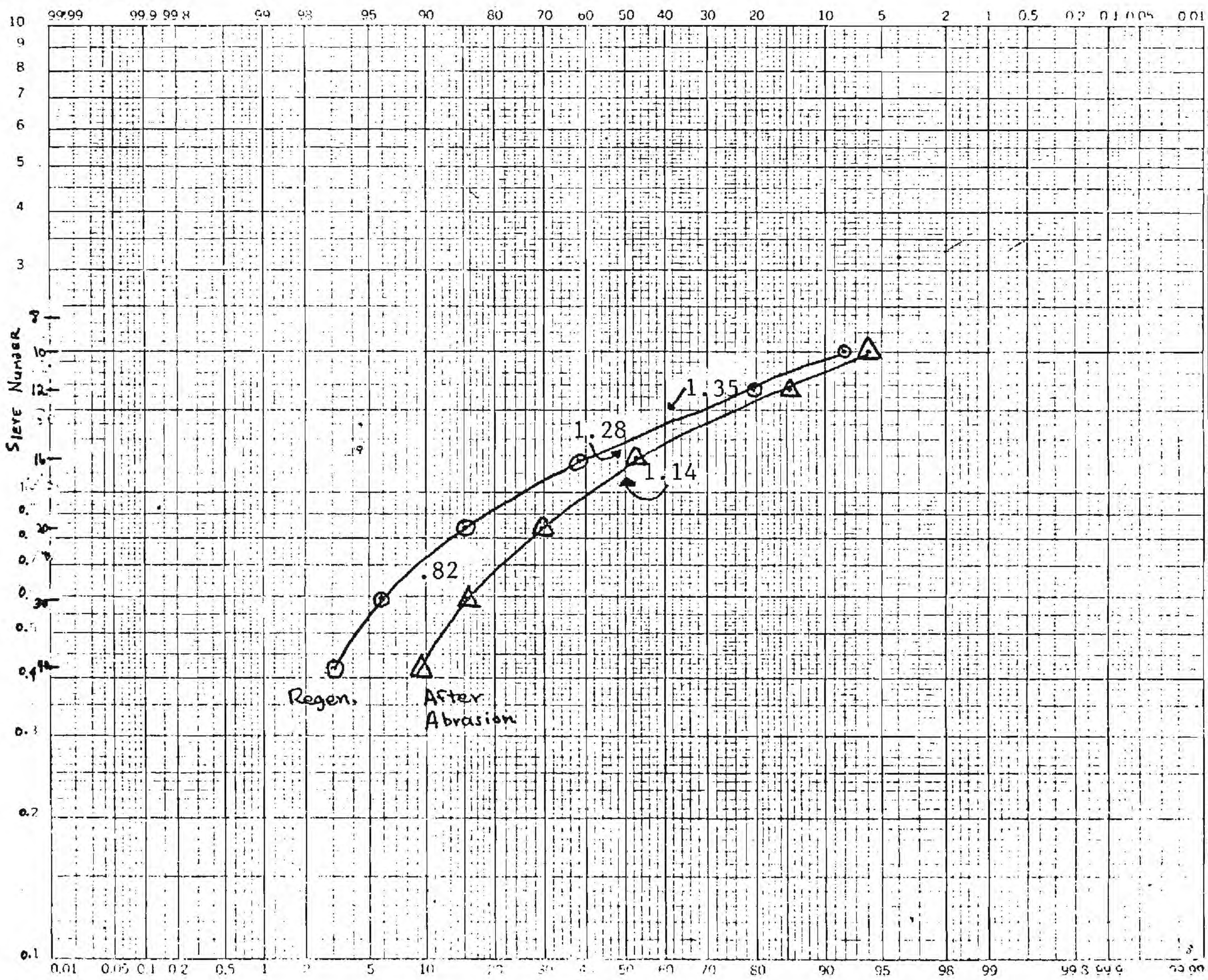
Cumulative % Passing

FIGURE 9

PARTICLE SIZE DISTRIBUTION

MANCHESTER WATERWORKS
No. 8-Regenerated

Cells 77,88,99

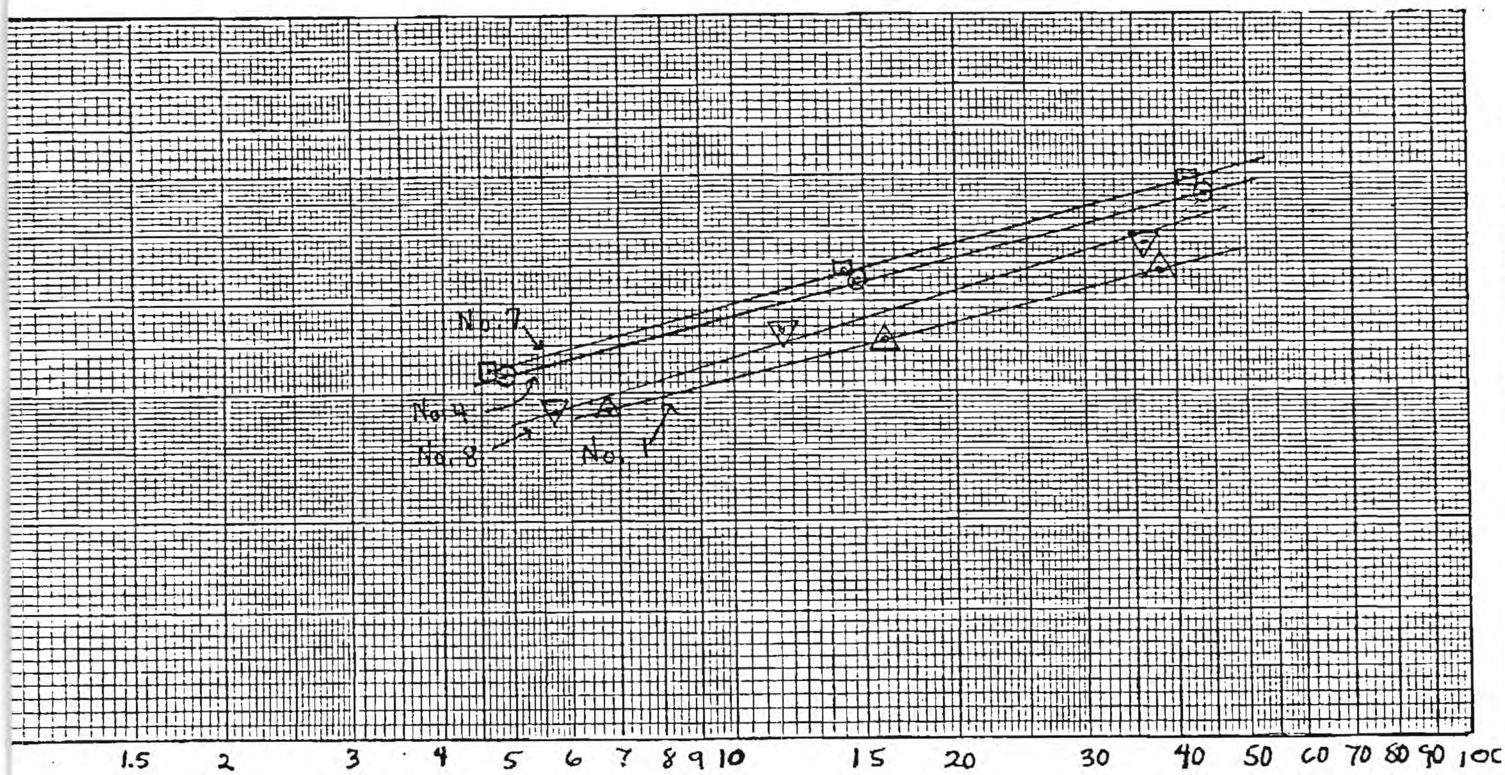


Cumulative % Passing

FIGURE 10

PHENOL ISOTHERMS

For MPV Determinations

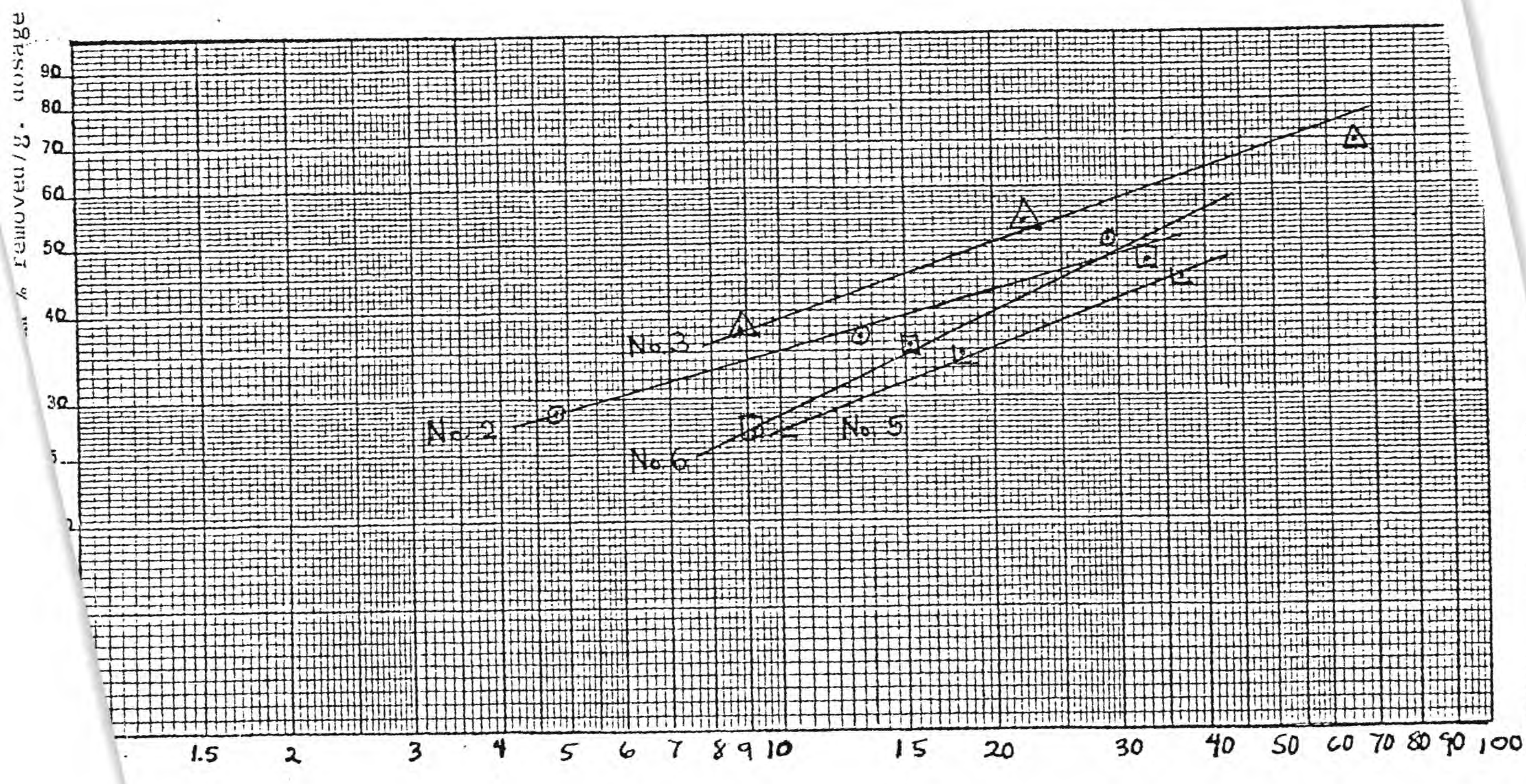


Final Phenol Concentrations (%)

FIGURE 11

PHENOL ISOTHERMS

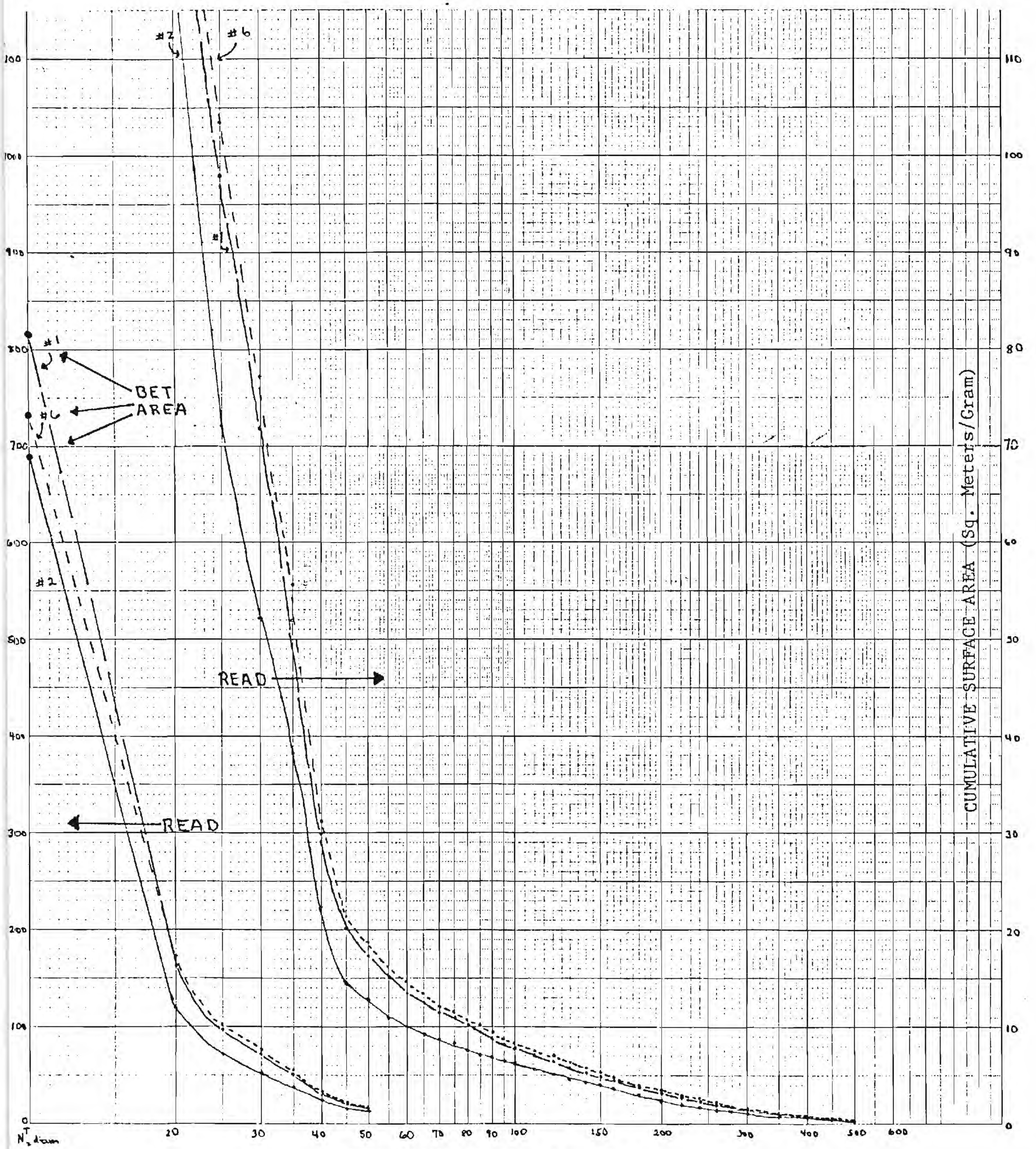
For MPV Determinations



Final Phenol Concentrations (%)

FIGURE 12

SURFACE AREA DISTRIBUTION FROM THE NITROGEN DESORPTION ISOTHERM



PORE DIAMETER (Angstroms)

FIGURE 13

SURFACE AREA DISTRIBUTION FROM THE NITROGEN DESORPTION ISOTHERM

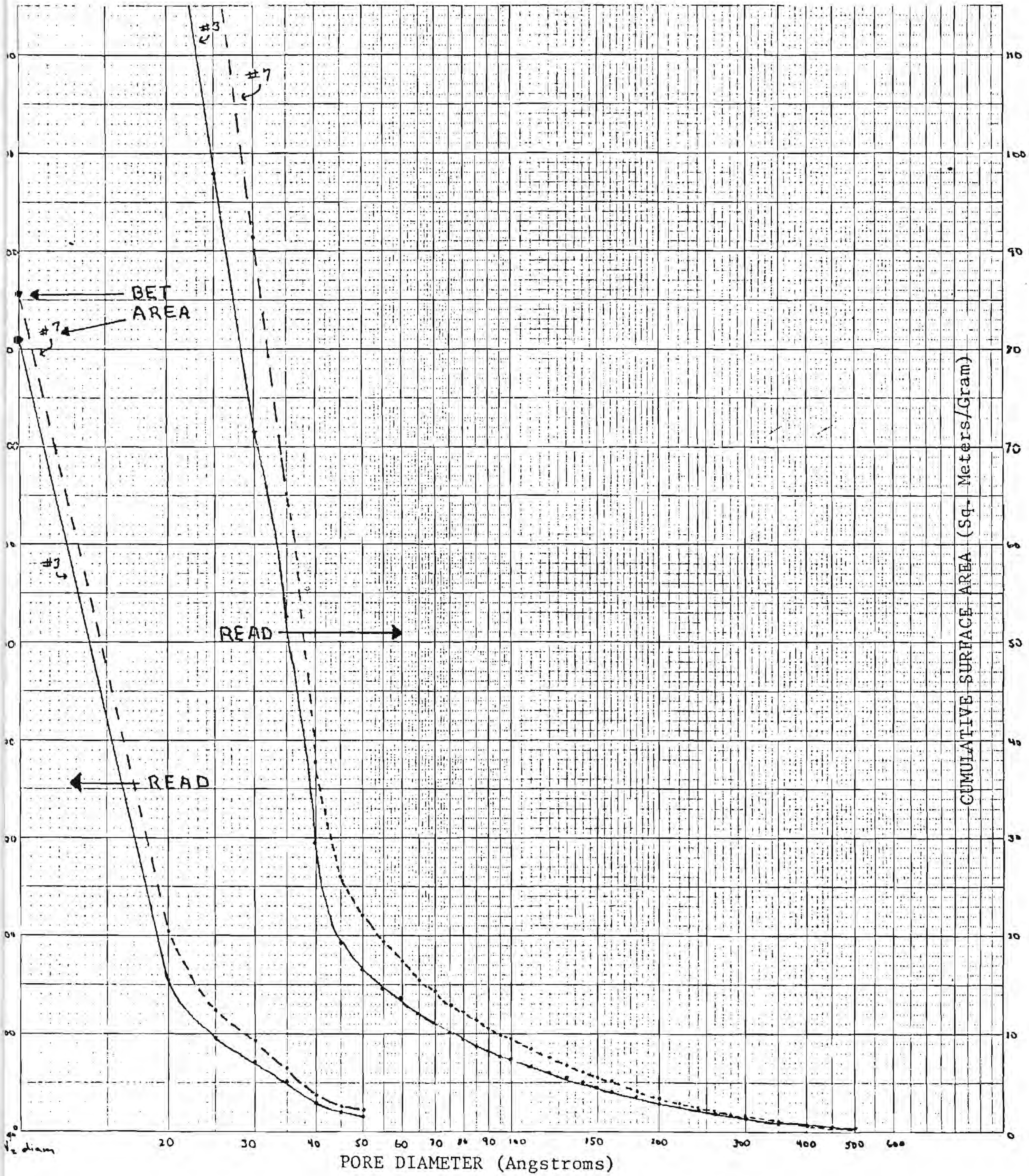
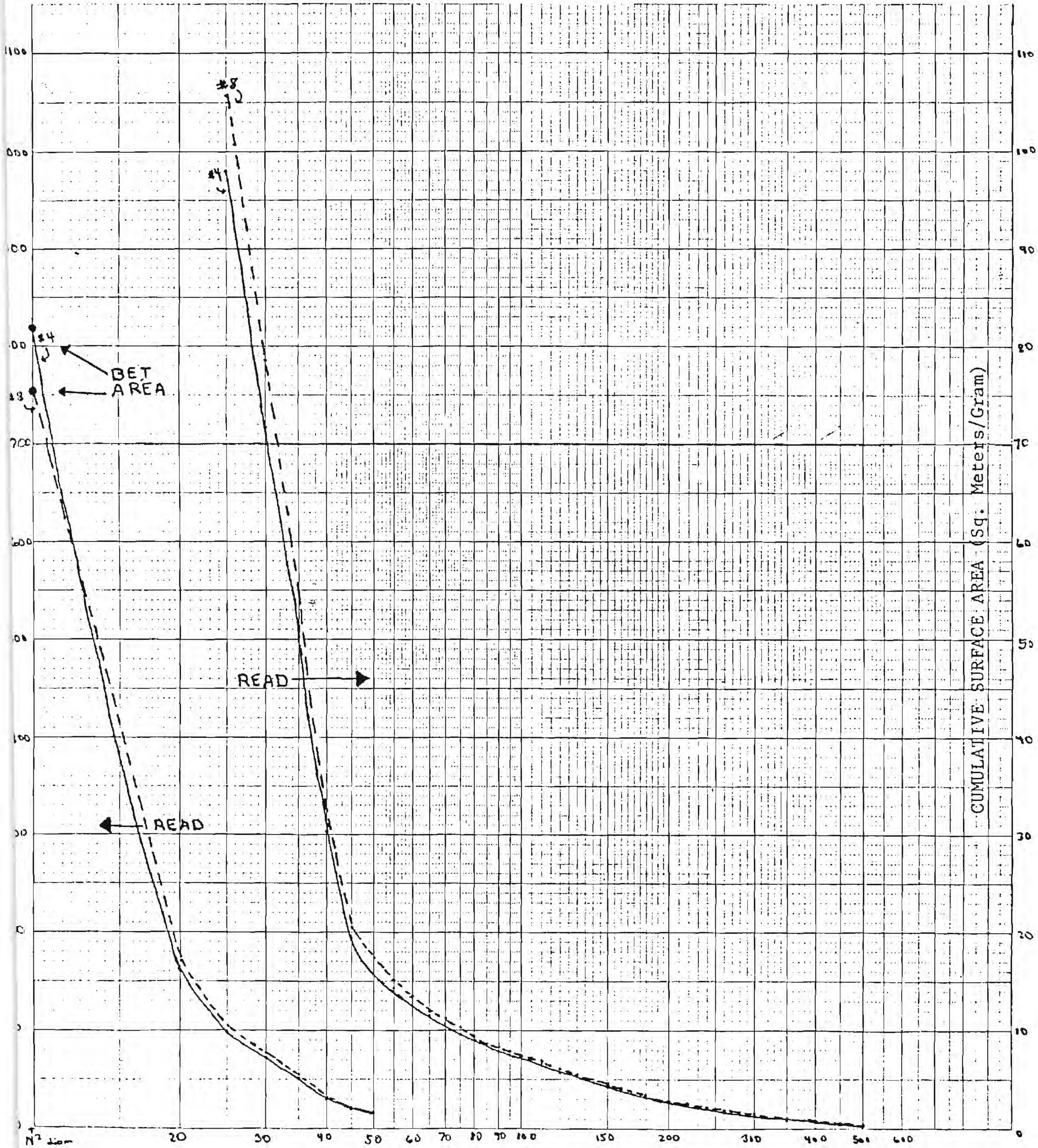


FIGURE 14

SURFACE AREA DISTRIBTUION FROM THE NITROGEN DESORPTION ISOTHERM



PORE DIAMETER (Angstroms)

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80 Grade (if known): Westvaco WVW 8 x 30

Designation: No.1 Composite Cells 11,22,33 - Spent

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average
Abrasion No. (Ro-Tap)	%	85.7		
* Iodine No.	mg/g	782	778	780
Surface Area, BET N_2 (1)	m^2/g	(814 Calcined sample)		
* Molasses Decolorizing Index (d.b.)	-	3.7	3.9	3.8
Moisture, w.b.	%	5.70		
* Volatile Matter, d.b.	%	15.63	14.22	14.93
* Ash, Total d.b.	%	5.39	5.44	5.42
Particle Size (U.S. Sieve #)	nominal	8x30		
** Oversize (8)	%	8.50		
Undersize (30)	%	3.18		
Effective Size (10% smaller than)	mm	0.84		
Uniformity Coefficient (60%/10%)		1.79		
Mean Particle Diameter (Calc'd)	mm	1.45		
Median Particle Diam. (Graph 50%)	mm	1.40		
* Apparent Density	g/ml	0.667	0.667	0.667 (0.608 calcined)
* Modified Phenol Value, MPV				
Westvaco method, 790 Const.	ppm	25.3		
AWWA B600-78, 90 Const.	g/l	2.88		

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:
Stanton B. Smith, Ph.D.
Principal Research Scientist

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80)

Grade (if known): Westvaco WVW 8 x 30

Designation: No. 2 Spent Virgin-DS1

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average
Abrasion No. (Ro-Tap)	%	83.5		
* Iodine No.	mg/g	775	781	778
Surface Area, BET N_2 (1)	m^2/g	(687 calcined sample)		
* Molasses Decolorizing Index (d.b.)	-	3.9	3.9	3.9
Moisture, w.b.	%	4.58		
* Volatile Matter, d.b.	%	4.82	4.80	4.81
* Ash, Total d.b.	%	6.04	6.02	6.03
Particle Size (U.S. Sieve #)	nominal	8x30		
** Oversize (8)	%	6.4		
Undersize (30)	%	2.68		
Effective Size (10% smaller than)	mm	0.80		
Uniformity Coefficient (60%/10%)		1.88		
Mean Particle Diameter (Calc'd)	mm	1.41		
Median Particle Diam. (Graph 50%)	mm	1.38		
* Apparent Density	g/ml	0.625	0.628	0.627 (0.599 calcined)
* Modified Phenol Value, MPV				
Westvaco method, 790 Const.	ppm	22.6		
AWWA B600-78, 90 Const.	g/1	2.58		

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:____________________

Stanton B. Smith, Ph.D.
Principal Research Scientist

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CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80 Grade (if known):
Westvaco WVW 8 x 30

Designation: No. 3 Regenerated Virgin - QT 1

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average
Abrasion No. (Ro-Tap)	%	82.6		
* Iodine No. (1)	mg/g	1059	1048	1054
Surface Area, BET N_2 (1)	m^2/g	807		
* Molasses Decolorizing Index (d.b.)	-	5.7	5.7	5.7
Moisture, w.b.	%	2.25		
* Volatile Matter, d.b.	%	3.94	3.67	3.81
* Ash, Total d.b.	%	6.31	6.27	6.29
Particle Size (U.S. Sieve #)	nominal	8x30		
** Oversize (8)	%	4.3		
Undersize (30)	%	5.90		
Effective Size (10% smaller than)	mm	0.78		
Uniformity Coefficient (60%/10%)		1.77		
Mean Particle Diameter (Calc'd)	mm	1.29		
Median Particle Diam. (Graph 50%)	mm	1.25		
* Apparent Density	g/ml	0.587	0.590	0.589
* Modified Phenol Value, MPV				
Westvaco method, 790 Const.	ppm	20.3		
AWWA B600-78, 90 Const.	g/l	2.31		

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:____________________
Stanton B. Smith, Ph.D.
Principal Research Scientist

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80 Grade (if known):

Designation: No. 4 Composite Carbon, Regenerated Westvaco WVW 8 x 30

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average
Abrasion No. (Ro-Tap)	%	84.5		
*Iodine No. (1)	mg/g	965	974	970
Surface Area, BET N_2 (1)	m^2/g	816		
*Molasses Decolorizing Index (d.b.)	-	5.2	5.2	5.2
Moisture, w.b.	%	3.32		
*Volatile Matter, d.b.	%	7.67	6.99	7.33
*Ash, Total d.b.	%	6.18	6.08	6.13
Particle Size (U.S. Sieve #)	nominal	8x30		
**Oversize (8)	%	5.3		
Undersize (30)	%	5.03		
Effective Size (10% smaller than)	mm	0.73		
Uniformity Coefficient (60%/10%)		1.90		
Mean Particle Diameter (Calc'd)	mm	1.32		
Median Particle Diam. (Graph 50%)	mm	1.28		
*Apparent Density	g/ml	0.597	0.594	0.596
*Modified Phenol Value, MPV				
Westvaco method, 790 Const.	ppm	20.7		
AWWA B600-78, 90 Const.	g/l	2.36		

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:____________________

Stanton B. Smith, Ph.D.
Principal Research Scientist

ENGINEERING EXPERIMENT STATION

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CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80 Grade (if known): Westvaco WVW 8 x 30

Designation: No. 5 Composite cells 77,88,99, Spent

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average	
Abrasion No. (Ro-Tap)	%	81.5			
* Iodine No.	mg/g	798	797	798	
Surface Area, BET N_2 (1)	m^2/g				
* Molasses Decolorizing Index (d.b.)	-	3.5	3.3	3.4	
Moisture, w.b.	%	5.24			
* Volatile Matter, d.b.	%	13.94	13.10	13.52	
* Ash, Total d.b.	%	7.00	6.99	6.99	
Particle Size (U.S. Sieve #)	nominal	8x30			
** Oversize (8)	%	3.2			
Undersize (30)	%	2.30			
Effective Size (10% smaller than)	mm	0.85			
Uniformity Coefficient (60%/10%)		1.65			
Mean Particle Diameter (Calc'd)	mm	1.37			
Median Particle Diam. (Graph 50%)	mm	1.30			
* Apparent Density	g/ml	0.607	0.610	0.609	(0.573 Calcined)
* Modified Phenol Value, MPV					
Westvaco method, 790 Const.	ppm	2.93			
AWWA B600-78, 90 Const.	g/l	3.34			

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:

Stanton B. Smith, Ph.D.
Principal Research Scientist

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80 Grade (if known):
Westvaco WVW 8 x 30

Designation: No, 6 Spent

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average
Abrasion No. (Ro-Tap)	%	82.2		
* Iodine No.	mg/g	811	810	811
Surface Area, BET N_2 (1)	m^2/g	(730 Calcined Sample)		
* Molasses Decolorizing Index (d.b.)	-	3.9	3.9	3.9
Moisture, w.b.	%	3.98		
* Volatile Matter, d.b.	%	10.92	12.64	11.78
* Ash, Total d.b.	%	6.99	6.90	6.95
Particle Size (U.S. Sieve #)	nominal	8x30		
** Oversize (8)	%	5.2		
Undersize (30)	%	3.48		
Effective Size (10% smaller than)	mm	0.79		
Uniformity Coefficient (60%/10%)		1.81		
Mean Particle Diameter (Calc'd)	mm	1.37		
Median Particle Diam. (Graph 50%)	mm	1.34		
* Apparent Density	g/ml	0.604	0.607	0.606 (0.569 Calcined)
* Modified Phenol Value, MPV				
Westvaco method, 790 Const.	ppm	28.2		
AWWA B600-78, 90 Const.	g/l	3.21		

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:________________
Stanton B. Smith, Ph.D.
Principal Research Scientist

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CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80 Grade (if known): Westvaco WVW 8 x 30

Designation: No. 7 Composite Regenerated

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average
Abrasion No. (Ro-Tap)	%	77.9		
*Iodine No. (1)	mg/g	1012	1018	1015
Surface Area, BET N_2 (1)	m^2/g	854		
*Molasses Decolorizing Index(d.b.)	-	5.4	5.6	5.5
Moisture, w.b.	%	140		
*Volatile Matter, d.b.	%	4.52	3.97	4.25
*Ash, Total d.b.	%	7.62	7.45	7.54
Particle Size (U.S. Sieve #)	nominal	8x30		
**Oversize (8)	%	1.8		
Undersize (30)	%	9.30		
Effective Size (10% smaller than)	mm	0.72		
Uniformity Coefficient (60%/10%)		1.71		
Mean Particle Diameter (Calc'd)	mm	1.17		
Median Particle Diam. (Graph 50%)	mm	1.10		
*Apparent Density	g/ml	0.571	0.574	0.573
*Modified Phenol Value, MPV				
Westvaco method, 790 Const.	ppm	20.0		
AWWA B600-78, 90 Const.	g/l	2.28		

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:________________

Stanton B. Smith, Ph.D.
Principal Research Scientist

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CARBON ANALYSIS REPORT

SAMPLE:

Source: Manchester Water Works (Received 9/16/80 Grade (if known): Westvaco WVW 8 x 30

Designation: No. 8 Composite cells 77,88,99, Regenerated

Project No.: A-2584

ANALYTICAL RESULTS (by Westvaco Standard Methods unless otherwise noted)

TEST	Units	RESULTS Replicates (1)	(2)	Average
Abrasion No. (Ro-Tap)	%	85.3		
* Iodine No. (1)	mg/g	896	896	896
Surface Area, BET N_2 (1)	m^2/g	754		
* Molasses Decolorizing Index (d.b.)	-	4.9	4.7	4.8
Moisture, w.b.	%	3.19		
* Volatile Matter, d.b.	%	6.53	5.86	6.20
* Ash, Total d.b.	%	7.20	7.22	7.21
Particle Size (U.S. Sieve #)	nominal	8x20		
** Oversize (8)	%	2.0		
Undersize (30)	%	5.79		
Effective Size (10% smaller than)	mm	0.82		
Uniformity Coefficient (60%/10%)		1.72		
Mean Particle Diameter (Calc'd)	mm	1.32		
Median Particle Diam. (Graph 50%)	mm	1.28		
* Apparent Density	g/ml	0.589	0.592	0.591
* Modified Phenol Value, MPV				
Westvaco method, 790 Const.	ppm	23.8		
AWWA B600-78, 90 Const.	g/l	2.71		

NOTES AND REMARKS:

(1) Micromeritics automated method
* Corrected for trace of moisture remaining after drying
** Estimated from plot of screen analysis

Signed:____________________
Stanton B. Smith, Ph.D.
Principal Research Scientist